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Abstract
Survival estimates measured from the time of a cancer diagnosis become less informative after one or two years' survival. Using records from the Canadian Cancer Registry linked to the Canadian Vital Statistics Death Database, five-year conditional relative survival ratio (RSR) estimates were derived for a large number of cancers. For each cancer with an initial five-year RSR of at least 80% (except breast cancer), a conditional five-year RSR of 95% or more was achieved after five years' survival. Among cancers with initial five-year RSRs of 50% to 79%, a five-year conditional RSR of 95% or more was observed for cancers of the cervix uteri and colon after five years. There was no apparent improvement in survival prospects during the first five years after diagnosis for chronic lymphocytic leukemia (CLL). Despite initial prognoses of less than 50%, a conditional five-year RSR of at least 90% five years after diagnosis was achieved for stomach cancer and leukemia (excluding CLL).

Keywords
neoplasms, population surveillance, prognosis, registries, survival analysis

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Survival statistics are an indicator of the effectiveness of cancer detection and treatment.[1] These statistics are used to compare cancer control over time[2] and across jurisdictions.[3,4] They are also of interest to clinicians providing direct care and to patients, who usually want an estimate of their prognosis.[5]

Survival estimates are typically presented as the probability—or the ratio of observed and expected probabilities in the case of relative survival—of surviving a given length of time (for example, five years) after diagnosis. However, these estimates are less informative for people who have survived one or more years, as the risk of death due to cancer is often greatest in the first few years. After this initial period, the prognosis can improve substantially, so the earlier estimates no longer apply.[6] The outlook for such people can be estimated more appropriately using *conditional* survival.

For the first time in Canada, predicted conditional relative survival estimates are presented for a large number of cancers. Cancers with the greatest relative improvement in prognosis since diagnosis are highlighted. Cancers showing less improvement are also identified.

Prognosis improves over time

For almost all the individual cancers studied, the relative probability of living an additional five years improved when measured at increasingly longer periods after diagnosis, the effect being strongest in the first one to two years (Table 1). A notable exception was chronic lymphocytic leukemia (CLL), for which five-year relative survival was just under 80% at diagnosis and did not appear to improve over the subsequent five years.

After five years' survival, the conditional five-year relative survival ratio (RSR) had risen to at least 95% for the cancers with an initial five-year RSR of at least 80%. The exception was breast cancer (five-year RSR of 93% after five years). Thyroid, prostate and testicular cancers had five-year prognoses of 95% or more at diagnosis; for skin melanoma and cancer of the corpus uteri, this level was achieved after three years, and for Hodgkin lymphoma, it took five years.

Table 1
Predicted five-year relative survival ratios (RSR), by type of cancer and conditional on having survived up to five years, Canada excluding Quebec, 2004 to 2006

Cancer type	RSR conditional on surviving (years)					
	0	1	2	3	4	5
	%					
Thyroid	98	100	100	100	99	99
Prostate	96	97	98	99	99	99
Testis	95	98	99	99	100	100
Skin melanoma	90	92	94	96	97	98
Breast	88	89	90	91	92	93
Corpus uteri	85	90	94	96	98	98
Hodgkin lymphoma	85	92	93	94	94	95
Chronic lymphocytic leukemia (CLL)	77	80	79	78	79	78
Cervix uteri	73	82	87	92	94	96
Bladder (including in situ)	73	83	88	90	93	94
Kidney and renal pelvis	67	83	88	91	92	94
Soft tissue	65	79	86	90	92	93
Larynx	64	72	78	81	80	83
Rectum	64	73	79	84	90	93
Colon	63	77	85	90	94	97
Non-Hodgkin lymphoma	63	78	82	83	84	85
Oral (buccal cavity and pharynx)	63	74	82	86	88	88
Ovary	42	53	61	69	76	82
Multiple myeloma	37	45	47	51	55	60
Leukemia (excluding CLL)	34	65	77	78	88	90
Stomach	24	49	68	80	87	92
Brain	23	47	65	71	75	78
Liver	18	42	55	67	74[†]	82[†]
Lung and bronchus	16	37	54	65	71	75
Esophagus	13	34	56	69	77	83[†]
Pancreas	6	28	54	68	79	88[†]

[†] standard error of 3.0% or more; no estimates have standard errors of 3.3% or more
Source: Canadian Cancer Registry, Statistics Canada and provincial/territorial cancer registries.

A five-year conditional RSR of 90% or higher was achieved for breast cancer after two years, and by one year for all other cancers in this group.

Among cancers with five-year RSRs of 50% to 79% at diagnosis, a five-year conditional RSR of 95% or higher was observed for cancers of the cervix uteri and colon after five years. A five-year conditional RSR of 90% or higher was achieved for cancers of the bladder, kidney and renal pelvis, and soft tissue after three years, and for rectal cancer, after four years. It was not achieved for the other cancers with initial five-year RSRs of 50% to 79%, although improvements from the mid-sixty percents at diagnosis to the mid-eighty percents among those surviving the first five years were noted for oral and laryngeal cancers, and for non-Hodgkin lymphoma. The apparent lack of improvement in prognosis over time for people diagnosed with CLL was unique among the cancers associated with at least a little excess mortality at diagnosis. This is consistent with findings reported in a recent study using Surveillance, Epidemiology and End Results data from the United States.[7]

A much better expectation of continued survival than at diagnosis was achieved for all cancers for which the initial five-year relative prognosis was less than 50% (Figure 1). Nonetheless, the five-year conditional RSR remained below 90% five years after diagnosis for all but two cancers in this group. Stomach cancer and leukemia (excluding CLL) reached a 90% five-year conditional RSR after five years' survival—despite original prognoses of 24% and 34%, respectively. The lowest five-year relative survival estimates at diagnosis were for cancers of the esophagus (13%) and pancreas (6%); however, by the fifth year of survival, both had five-year conditional RSRs in the mid- to upper-eighty percent range. The corresponding improvement for multiple myeloma (from 37% to 60%) was more modest.

Ranking of five-year RSRs

Cancers of the pancreas and colon showed the most striking improvements in the ranking of five-year RSRs from diagnosis to five years later (Table 2). Among the cancers studied here, pancreatic cancer ranked 26th at diagnosis, but given five years' survival, it ranked 16th. Colon cancer rose from 15th to 6th position. Cancers of the stomach and esophagus, and leukemia (excluding CLL) improved seven, six and five positions, respectively.

A substantial drop in ranking—from 8th to 23rd position—was observed for CLL, due largely to the lack of a predicted increase in relative survival among those surviving the first five years after diagnosis. The rankings of multiple myeloma, breast and larynx each fell six to seven positions, indicating that survival had not improved to the same degree as for many other cancers.

Patterns similar for males and females

Cancer-specific patterns in relative survival conditional on surviving one to five years after diagnosis were generally similar by sex (data not shown). For example, at diagnosis, the five-year RSRs for rectal cancer were 63% for males and 65% for females; at five years' survival, the figures were 92% and 94%, respectively.

In some instances, an apparent sex-specific survival advantage at diagnosis disappeared during the first five years of follow-up. Five-year RSRs at diagnosis were at least four percentage points higher for females than males for skin melanoma, lung and bronchial cancer, Hodgkin lymphoma and brain cancer, but differed by no more than one percentage point at or before the fifth anniversary of diagnosis (data not

The data

Cancer incidence data are from the July 2010 version of the Canadian Cancer Registry (CCR), a dynamic, person-oriented, population-based database maintained by Statistics Canada. The CCR contains information on cases diagnosed from 1992 onward, compiled from reports from every provincial/territorial cancer registry.

A file containing records of invasive cancer cases and in situ bladder cancer cases (the latter are reported for each province/territory except Ontario) was created using the multiple primary coding rules of the International Agency for Research on Cancer.[9] Cases were classified based on the *International Classification of Diseases for Oncology, Third Edition*[9] and grouped using Surveillance, Epidemiology, and End Results Program grouping definitions, with mesothelioma and Kaposi's sarcoma as separate groups.[10]

Mortality through December 31, 2006 was determined by record linkage to the Canadian Vital Statistics Death Database (excluding deaths registered in the province of Quebec), and from information reported by provincial/territorial cancer registries. For deaths reported by a provincial registry but not confirmed by record linkage, the date of death was assumed to be that submitted by the reporting registry.

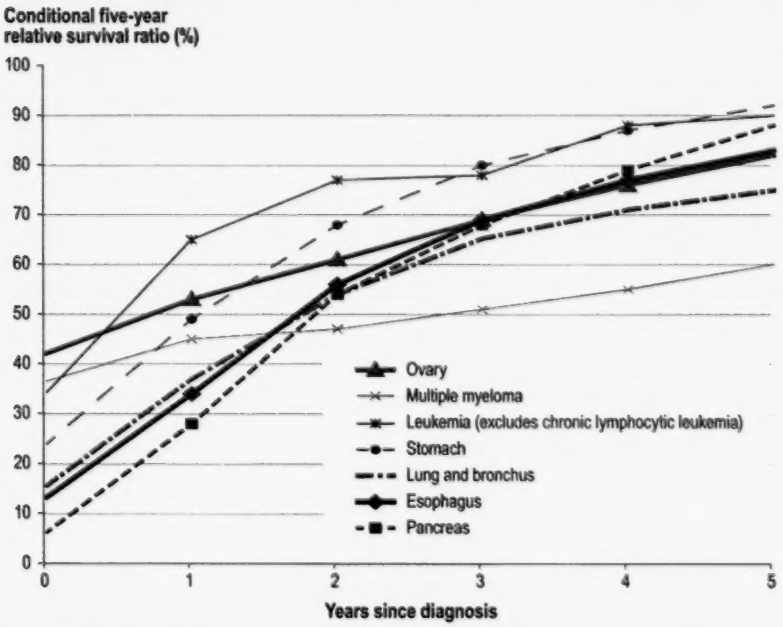
Analyses were based on all primary cancers—an approach that is becoming standard practice.[11-13] Data from the province of Quebec were excluded from the analysis primarily because of issues associated with correctly ascertaining the vital status of cases. Records were also excluded if: age at diagnosis was younger than 15 or older than 99; diagnosis was established through autopsy only or death certificate only; or the year of birth or death was unknown.

In the context of cancer, conditional survival is the probability of living an additional number of years (y) given that the person has already survived a fixed number of years (x) since diagnosis. The measure can be obtained by dividing the cumulative survival at x + y years by the cumulative survival at x years. Conditional five-year relative survival expresses the likelihood of surviving five years into the future at various points since diagnosis, relative to the expected survival of similar people in the general population.[14]

Relative survival was estimated as the ratio of the observed survival for people diagnosed with cancer to the survival expected for the general population with the same sex, age, province/territory at time of diagnosis and time period. When a relative survival ratio (RSR) reaches 100%, survival for those diagnosed with cancer is similar to that of an otherwise comparable group in the general population. RSRs were derived using the period method,[15,16] which provides more timely estimates of cancer survival.[17-20] When survival is generally improving, a period estimate tends to be a conservative prediction of the survival that is eventually observed.[17-20]

Survival analyses were based on a publicly available algorithm[21] to which minor adaptations were made. Expected survival proportions were derived from sex- and period-specific complete provincial life tables using the Ederer II approach.[22] Further detail on the survival methodology is provided elsewhere.[23] For descriptive purposes, cancers were initially grouped according to the five-year survival prognosis at diagnosis: good (80% or more), fair (50% to 79%), and poor (less than 50%).

Figure 1
Five-year predicted conditional relative survival ratios, selected cancers, Canada excluding Quebec, 2004 to 2006



Source: Canadian Cancer Registry, Statistics Canada and provincial/territorial cancer registries.

shown). Similarly, an apparent survival advantage for men diagnosed with bladder cancer disappeared relatively soon after diagnosis (data not shown).

Conclusion

The conditional survival estimates presented here are population-based, and therefore, reflect the average survival time of large groups of people rather than an individual's prognosis. Even so, the figures are a useful update of the initial prognosis for a number of cancers, and are generally a cause for optimism. For most cancers, the outlook for people who have survived one or more years after diagnosis is better than that at diagnosis, sometimes substantially so. For some cancers for which survival was already very promising, such as thyroid cancer, little additional improvement could be expected.

Conditional survival data provide more accurate prognostic information about how the risk of death changes over time. These results could assist people who have survived one or more years after a cancer diagnosis in

Table 2
Relative rank of cancer type based on predicted five-year relative survival ratio (RSR) at diagnosis and conditional on having survived five years, Canada excluding Quebec, 2004 to 2006

Cancer type	Five-year RSR rank		
	At diagnosis	Conditional on surviving five years	Change in rank
Testis	3	1	2
Thyroid	1	2	-1
Prostate	2	2	0
Skin melanoma	4	4	0
Corpus uteri	6	4	2
Colon	15	6	9
Cervix uteri	9	7	2
Hodgkin lymphoma	6	8	-2
Bladder (including in situ)	9	9	0
Kidney and renal pelvis	11	9	2
Rectum	13	11	2
Soft tissue	12	11	1
Breast	5	11	-6
Stomach	21	14	7
Leukemia (excluding CLL)	20	15	5
Oral (buccal cavity and pharynx)	15	16	-1
Pancreas	26	16	10
Non-Hodgkin lymphoma	15	18	-3
Esophagus	25	19	6
Larynx	13	19	-6
Ovary	18	21	-3
Liver	23	21	2
Brain	22	23	-1
Chronic lymphocytic leukemia (CLL)	8	23	-15
Lung and bronchus	24	25	-1
Multiple myeloma	19	26	-7

Source: Canadian Cancer Registry, Statistics Canada and provincial/territorial cancer registries.

adjusting their view of the future, and help cancer care providers in planning follow-up. Calculations of conditional survival for individual cancers by subsite or histological subtype and by age group would further inform clinical understanding. ■

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